WFO Taunton Post Event Analysis
Event 2005_02
"Examining the Snowstorm of February 28-March 1, 2005; A Missed Event for Cape Cod, Massachusetts"

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INTRODUCTION

A fast moving and very compact winter storm impacted the WFO Taunton County Warning Area (CWA) during the late afternoon and evening of February 28, lasting into the morning hours of March 1. While forecasts and warnings handled the moderate snowfall across the interior northeast quite well, they did not handle the significant snowfall that occurred on Cape Cod until the event was well underway during the evening of the 28th. A widespread area of 5 to 10 inches fell across the interior part of the CWA, with the maximum snowfall occurring along the south coast and Cape Cod (see Figure 1).

The complexities of this storm included some remarkable model divergence in storm evolution, caused in part by the complexity of a northern and southern stream impulse, as well as the more common impact of onshore flow and low level warming with the expectation that rain would be the primary occurrence on Cape Cod and the Islands.

SYNOPTIC SETTING

A much energized northern and southern stream existed during the weekend of February 26 and 27. Very early in the forecast cycle, the NAM and GFS models were indicating that the northern shortwave would phase with the southern stream, causing the developing cyclone in the Gulf of Mexico to advance rapidly north-northeast through the spine of the Appalachians and into upstate New York. This solution would produce a snow to rain scenario for the northeast United States.

By 00Z on Sunday, February 27, the far inland NAM solution became the outlier and most other model solutions, including the Operational GFS runs were keeping the streams separate and forecasting the Gulf low to maintain its own identity and move swiftly northeast up the coast, with the center passing between Cape Cod and the waters southeast of Nantucket Island during the early morning of March 1.

In examining the GFS ensemble members, some spread existed amongst members. Storm tracks ranged from a cluster crossing southern New England to a colder suite of solutions, favored by the ECMWF, to pass near the bench mark of 40N and 70W. The GFS solution near the benchmark proved to be the correct solution, but it did not sufficiently resolve the low level cold air issues on Cape Cod and the islands.

Part of this spread may have been related to the way the models handled a deep closed low moving northwest through Labrador. Early in the weekend, the NWP was forecasting this low to head nearly due north and rapidly relax the confluent flow placed across extreme northern New England. By the 00Z runs on the 28th, it was apparent that the models had begun to resolve this closed low differently with the GFS having a better handle on its eventual west to northwest movement which maintained more ridging and confluence to the north of New England. In addition, GFS solutions were also showing a favorable heavy snow environment with strong frontogenesis and vertical motion through a deep layer of the atmosphere, maximizing snow growth potential. The 00z/28th run placed this axis across the south coast and Cape Cod north to about Worcester, then later runs backed the area farther inland. The low level thermal profiles indicated about a 200 mb deep warm layer over the south shore which would have resulted in rain rather than snow.

One interesting aspect of this storm as noted by several runs of the GFS between the 27th and 28th, was a hybrid appearance. For several runs, the GFS actually suggested there would be a quasi-warm core at 500 mb – closing off several warmer isotherms as low as -16 C surrounded by -20C and colder. The model also indicated a pronounced low level Potential Vorticity (PV) field, likely due in part to the strong vertical motion and diabatic heating induced by the frontogentic forcing (Figures 2 and 3). While it might be a stretch of the imagination, this PV configuration is not unlike that seen with transitioning tropical cyclones.

Low pressure moved northeast up the coast, intensifying at a rate of 4 to 6 millibars every 6 hours, passing just southeast of Cape Cod with a central pressure of 980 mb. This system displayed a frequent amount of lightning as it approach the coast of southern New England. A fast moving energetic band of frontogentically forced heavy snow overspread the region during the afternoon, reaching Cape Cod around 21Z. In spite of a developing 20 to 30 kt east to northeasterly flow, surface temperatures did not respond, and the south coast and Cape Cod proceeded to receive 8 to 13 inches of heavy wet snow in about an 8 hour period from 22Z to about 06Z on March 1. The only locations to change to rain were Chatham (CQX) and Nantucket Island (ACK), where the change lasted for only 4 hours.

Forecasts called for the axis of heavy snow to lie along and northwest of the I-95 corridor. While warning criteria snow did fall in this region, the maximum snowfall actually fell along the south coast and Cape Cod. Winter Weather Advisories were issued during the afternoon of the 28th, and were subsequently upgraded to warnings around 10 pm, but by this time, most of the heavy snow had already accumulated. It is difficult to isolate the primary source of model error. Periodic flare-ups of convection during the storm's life cycle may have played a role. Precipitation intensity perhaps was able to overcome some of the expected low level warming. Another factor is that sea surface temperatures just off the coast where at their climatological minimum. This could have added in retarding the boundary layer warming and could to at least a small degree compensated for the lack of a strong high to the north of the region. Even the RUC guidance failed to correctly capture the storm's track over the bench mark, as late as

its 18Z forecast cyclone on the 28th. With its farther west track, the model had a significantly deep layer of above freezing temperatures overspreading southeast coastal New England with a mostly rain event on the south coast and Cape Cod.

Coastal flooding and high winds were of concern during this event, due in part to the high astronomical tide cycle affecting the region at the end of February and the anticipation of a period of strong east to northeast winds. GFS runs on February 28th were indicating the potential for a period of gale force to storm force northeasterly flow for a 12 to 18 hour period along the east coast of Massachusetts. Later runs of the GFS continued this forecast but moved the strongest corridor of wind farther north up the New England coast. Extra-tropical storm surge guidance from the GFS model produced surge forecasts as high as 3 feet coinciding with the time of high tide along the eastern Massachusetts coast. WNA guidance was forecasting seas approaching 20 feet just off the Massachusetts shoreline. Local research has shown that moderate coastal flooding will commence with a combined storm tide of 12 feet at the Boston Harbor Tide Gage when combined with seas at or in excess of 20 feet. With these conditions present in the model guidance, coastal flood watches and warnings were issued for eastern Massachusetts.

WARNING PERFORMANCE

Overall, Hazardous Weather Outlooks as early as Friday, February 25, were indicating the increasing potential for a winter storm focused over the interior parts of the region. By Sunday morning, the focus was moving more toward a widespread winter event. Winter Storm Watches were issued at 5 am Sunday, February 27 for the entire forecast area, except Cape Cod and the Islands. The NCEP WWE guidance at 09Z on the 27th placed an axis of heavy snow across the south coast, Cape and Islands. Internal office discussions with neighboring offices and HPC indicated that confidence was low and that HPC was going solely with the 00Z GFS solution. Later WWE guidance through the morning of the 28th moved the axis back inland across the WFO BOX CWA.

Forecasters were confident at least through 12Z on the 28th, that the onshore flow would produce a rather rapid change to rain across southeast coastal Massachusetts and Cape Cod. GFS forecasts showed boundary layer temperatures rising to +4C and 850 mb temperatures rising to between +2 and +4C at the height of the event. By late in the afternoon on the 28th, however, forecasters realized that the warm easterly inflow was very slow in developing and GFS model forecasts continued to trend the system southeast and colder across the south coast, Cape Cod and the islands. Afternoon forecast updates shifted the warning area south and east but only upgraded to an advisory on Cape Cod and the Islands. The evening shift eventually upgraded to warnings, but lead time was minimal at best.

PODs were high for the event, with warnings correctly capturing the potential for around 1 foot of snow in the Merrimack Valley. Forecasts and warnings also correctly captured the sharp drop in snowfall amounts in much of the Connecticut Valley. However, forecasts failed to capture the foot or more of snow which fell along the south shore of

Boston and especially across Cape Cod and Martha's Vineyard. Watch, Warning and Advisory verification is provided in Table 1.

With respect to coastal flooding, mostly minor flooding and splash over occurred around the time of high tide late on the 28th primarily focused from Boston Harbor northward. Also, high wind watches, warnings and advisories did not verify.

In retrospect, this storm system produced only a 6 to 8 hour period of near gale force winds, focused around the time of the storm center's passage near Nantucket Island. The limited duration of onshore winds was unable to build large seas. The resulting storm surge for this storm was generally 1 to 1.5 feet, half of what earlier GFS based extratropical surge guidance was predicting.

LESSONS LEARNED

This event illustrates the importance of maintaining situational awareness and having knowledge of model trends in the forecast. While the GFS solutions were certainly not perfect, the model did correctly trend to the correct storm track. The presence of convection in a developing system continues to affect various NWP models, and to what degree this may have impacted the low level wind and thermal structure in the GFS and RUC is unknown. Upper air data and LAPS analyses began to suggest a colder solution during the afternoon of the 28th. Forecast teams did correctly trend the forecast colder and snowier in the southeast, but the hardest hit area of the south coast and Cape Cod was never really captured in our forecasts and warnings.

High wind events continue to pose a significant challenge. In spite of a deep surface low pressure system, the absence of a strong ridge of high pressure lead to a somewhat hybrid-tropical character to the storm system; a tight inner core of wind east of the center which produced gale force winds for only 6 hours. Typically, the coast of eastern New England will see a prolonged period of gale to storm force east to northeast flow with an approaching nor'easter, but the lack of strong high pressure to the north prohibited such a gradient driven wind field from evolving. This resulted in much less storm surge than was being forecast and a very minor coastal flood event.

SUMMARY

A fast moving and very compact winter storm impacted the WFO Taunton County Warning Area (CWA) during the late afternoon and evening of February 28, lasting into the morning hours of March 1. Grossly divergent model solutions made for a challenging forecast for this event. In addition, the very compact and concentrated nature of this storm system added to its complexity.

The Hazardous Weather Outlooks correctly identified and conveyed the potential for another major winter storm several days in advance. However, winter storm warnings failed to capture the intensity of the event on Cape Cod and the islands.

Lastly, the ECMWF was the first model to indicate a track over the bench mark and never deviate from that solution. WFO Taunton forecasters had noticed during this

winter, the ECMWF outperforming the NAM and GFS with several other winter storms. The ECMWF certainly helped support the family of GFS members forecasting the center to pass very close to the 40N/70W benchmark vs. the NAM solutions well to the west.

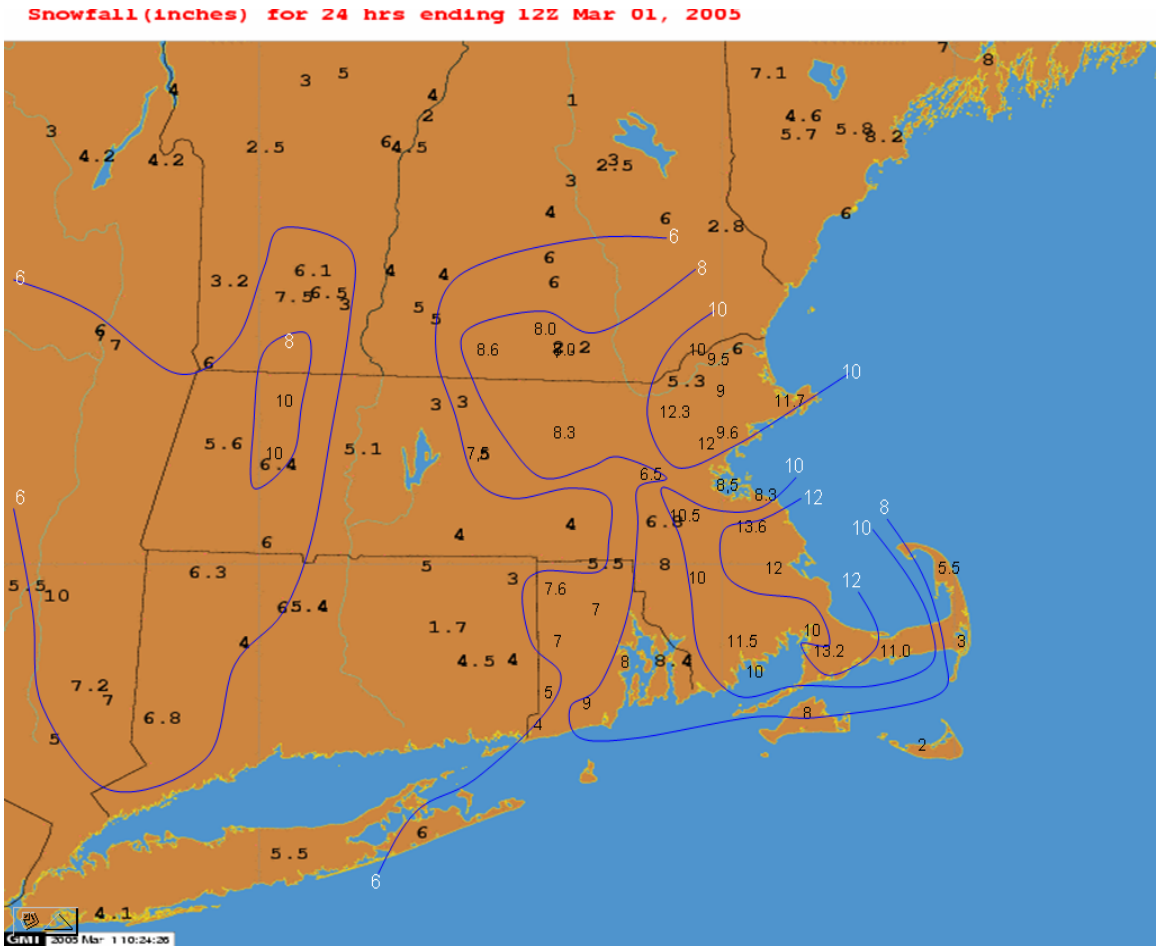

Figure 1. Storm total snowfall, February 28-March 1, 2005.

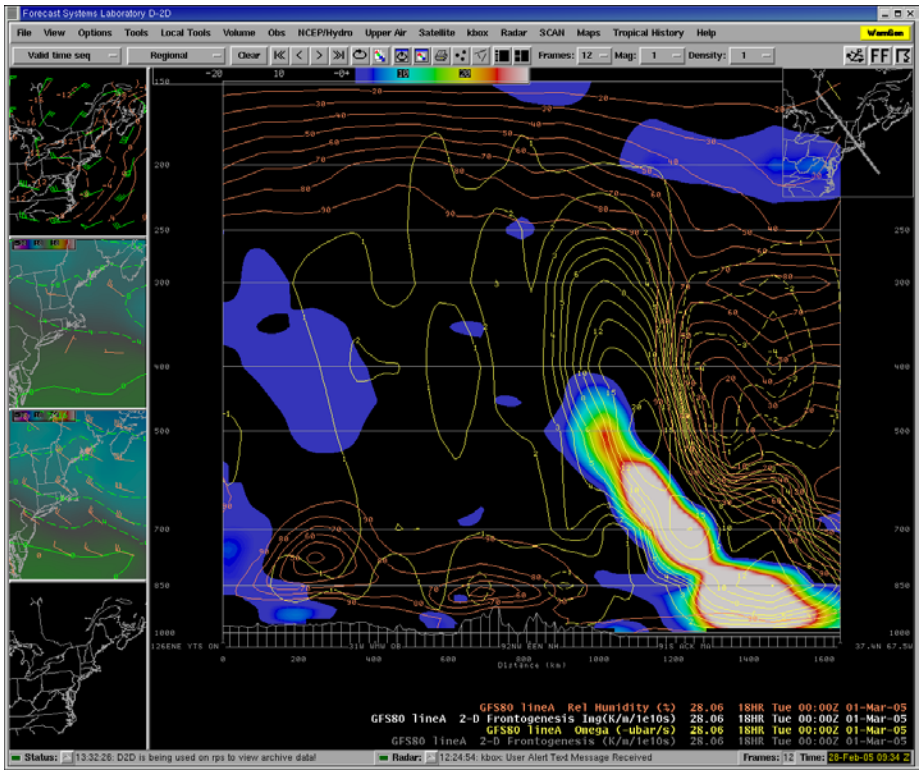

Figure 2. GFS 18 hour forecast valid 00Z Tuesday, March 1. Note the strong frontogenesis and upward vertical motion centered near Nantucket.

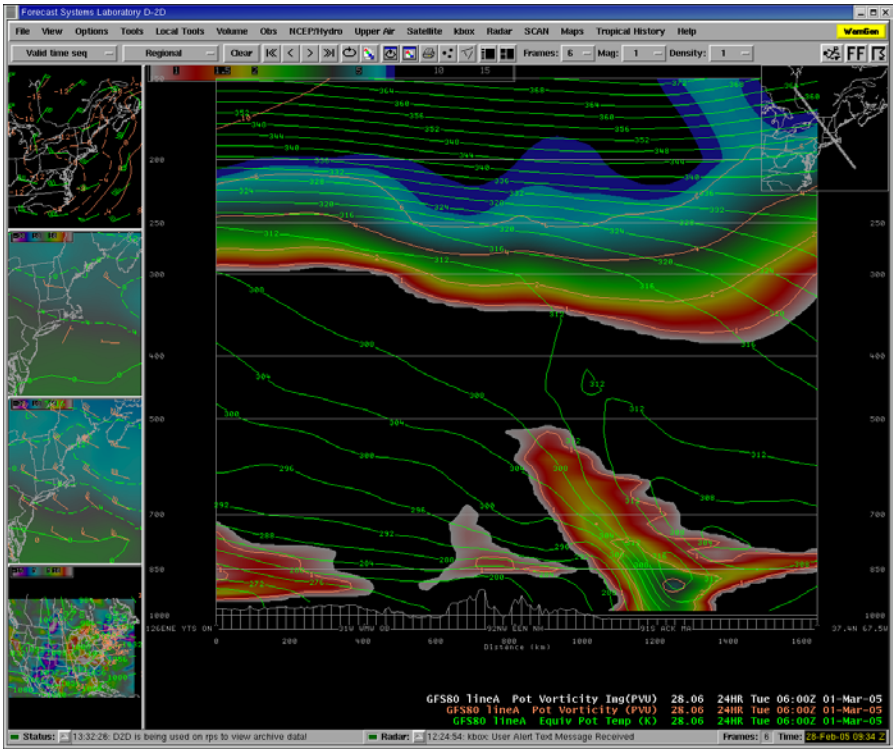

Figure 3. GFS 24 hour forecast valid 06Z Tuesday, March 1. Note the Pronounced PV region in the vicinity of Nantucket. Shading begins at a PV value of 1.5.

TABLE 1
Watch, warning and advisory preliminary verification

Hazard	POD	FAR	Lead Time
Winter Storm Watch	.94	.06	43 hours
Winter Storm Warning	1.0	0.03	23 hours*
Winter Weather Advisory	1.0	0.56	0
High Wind Watch	0	1.0	n/a
High Wind Warning	0	1.0	n/a
Wind Advisory	0	1.0	n/a
Coastal Flood Watch	0	1.0	n/a
Coastal Flood Warning	0	1.0	n/a

* While this lead time is impressive, Barnstable county received little if any lead time.